

## APPENDIX E

### Flexible Methodology Example

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#### **Definition of Detection Method, Failure Occurrence, and Severity Levels for Flexible RCM Analysis**

It should be understood that, from an overall perspective, flexible analysis approach focuses on subsystem and system level function loss. This is different from traditional analysis techniques, which focus on specific failure modes for specific components. Focus on the subsystem and system level allows RCM analysis to be conducted despite the absence of complete component level information.

#### **Detection Method**

As stated in the Ground Rules and Assumptions section, when system controls, automation configurations, and system safeguards are unknown, Detection Method Level can be assumed to be 1. This assumes and stresses that, for a mission critical facility, all item and system level function losses should and will be apparent.

Although this is an acceptable approach for initial analysis, and demonstration purposes, it should be understood that the presence, or absence, of detection method in a systems has a direct effect on the risk associated with the operation of that system. Therefore, consideration of detection method will provide more accurate and resolute analysis results and recommendations. Furthermore, an understanding of current detection method provisions, along with results of an analysis which considered detection method and component level failure modes, can and should be utilized to make recommendations on future detection method provisions.

#### **Occurrence**

Equipment specific PREP database availability numbers will provide indication of failure frequency. These metrics will help to provide less subjective item and system risk assessments. However, they must be adjusted to account for system redundancy, and ranked into discrete occurrence levels to be used in qualitative equipment criticality calculations.

By design and purpose, a redundant system is more reliable and less vulnerable than a single point, with respect to system function and mission requirements. Therefore, the occurrence level for a single point function must be weighted to reflect the operation, presumed reliability, and severity of loss of function of the redundant component system as accurately as possible.

The following formula is used to calculate the adjusted availability of a given subsystem due to a level of component or subsystem redundancy.

$$A_i^1 = \sum_{k=m}^n \frac{n!}{k!(n-k)!} (A_i)^k (1 - A_i)^{(n-k)}$$

Where:

$A_i$  = Initial inherent component availability

$A_i^1$  = Adjusted redundant component availability level

$m$  = Minimum number of components needed

$n$  = Number of components available

$k$  = Current component in redundant system being analyzed

With availability metrics representative of system configuration now available, component availability is ranked to provide discrete subsystem occurrence levels, as follows:

Availability (nines)	Occurrence Rank	Occurrence Description
$\geq 0.999999999$	1	Almost Never
0.999999999	2	Remote
0.99999999	3	Very Slight
0.9999999	4	Slight
0.999999	5	Low
0.99999	6	Medium
0.9999	7	Moderately High
0.99	8	High
0.9	9	Very High
0	10	Almost Certain

## Severity

It is also important to consider the concept of failure severity. Severity pertains to and ranks the consequences of system level failure mode effects. For example, a highly probable failure may occur for a subsystem of a piece of critical equipment without severe consequences.

Severity rankings used are as follows:

Ranking	Effect	Comment
1	None	No reason to expect failure to have any effect on Safety, Health, Environment or Mission
2	Very Low	Minor disruption to mission.
3	Low	Minor disruption to mission.
4	Low to Moderate	Moderate disruption to mission.
5	Moderate	Moderate disruption to mission.
6	Moderate to High	Moderate disruption to mission.
7	High	High disruption to mission.
8	Very High	High disruption to mission.
9	Hazard	Extremely high disruption to mission
10	Hazard	Extremely high disruption to mission.

### RPN Calculations and Ranking Methods for Flexible Analysis

Severity, occurrence, and detection method levels are then utilized to produce a subsystem risk assessment as follows:

$$RPN = O \times S \times D$$

Where:

RPN = Risk associated with failure mode (Risk Priority Number)

S = Severity level for failure mode

O = Occurrence level for failure mode

D = Detection method level (1)

This calculation will be performed for every subsystem item in the master equipment listing. With this information, Risk Priority Numbers for sub-systems and systems can be obtained as follows:

$$RPN_s = \sum_{n=1}^j (RPN_c)_n$$

Facility Identifier	Equipment Type	Parent System	M	N	PREP ID	A	A'	O' Ranked	S	RPN
A-1	A	X	1	2	13	0.999988924	0.9999999999	1	9	9
A-2	A	X	1	2	13	0.999988924	0.9999999999	1	9	9
B-1	B	X	1	4	163	0.999993654	1.000000000000	1	9	9
B-2	B	X	1	4	163	0.999993654	1.000000000000	1	9	9
B-3	B	X	1	4	163	0.999993654	1.000000000000	1	9	9
B-4	B	X	1	4	163	0.999993654	1.000000000000	1	9	9

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Where:

$RPN_s$  = Risk Priority Number for the current system being analyzed

$RPN_c$  = Risk Priority Number for the current subsystem

$n$  = The current subsystem being analyzed

$j$  = Total number of components in the sub-system or system

### Results – System X

Item and system risk assessments can now be utilized to apply RCM decision logic (see figure 5.2), and to build maintenance tasking program. Items and systems assessed to be of high operational risk should, especially, be applied to the decision logic and should receive high levels of maintenance focus. Items having extremely low operation risk will receive low levels of maintenance focus, and may be allowed to run to failure.